Section 6
Determination of Risk-Based Sediment and Floodplain Soil Concentrations

Risk and hazard estimates associated with ingestion of fish and contact with floodplain soils have been developed and are presented in Section 5. Based on these estimates, risk-based fish concentrations (RBC_{fish}) and sediment concentrations (RBC_{sed}) for PCBs were developed to be protective of sport and subsistence anglers. Further, risk-based floodplain soil concentrations (RBC_{soil}) were developed to be protective of residents living near or recreating on exposed floodplain soil. RBCs were developed for both cancer and noncancer endpoints. Risk-based concentrations were developed using an allowable cancer risk of 1 in 100,000 and a noncancer hazard quotient/index of 1.0.

6.1 Calculation of Risk-Based Fish Concentrations

RBC_{fish} were developed using the same risk and hazard algorithms used to derive risk and hazard estimates (Figures 3-2 and 3-3). To derive RBCs, the algorithm is reversed to solve for the concentration in fish associated with a specified cancer risk or hazard quotient, in this case 1 in 100,000 cancer risk or a hazard of 1.0. RBC_{fish} were derived using the same assumptions regarding ingestion rates, reduction factors, exposure frequencies, and duration. Table 6-1 presents estimated RBC_{fish}. Appendix B provides spreadsheets for all RBC calculations.

Table 6-1 Risk-Based Fish Fillet Concentrations (RBC_{fish}) [(1)] API/PC/KR Site

Receptor	RBC_{fish} Protective of 1E-05 Cancer Risk for PCBs (mg/kg)	RBC_{fish} Protective of 1.0 Hazard Quotient for PCBs (mg/kg)
Sport Angler - Central Tendency Assumes 24 meals/year 0.015 kg/day	0.109	0.187
Sport Angler - High End Assumes 125 meals/year 0.078 kg/day [(2)]	0.042	0.072
Subsistence Angler Assumes 179 meals/year 0.11 kg/day	0.015	0.025

(1) Concentrations protective of both carp and smallmouth bass. Hazard quotient for immunological endpoint. Because RBC_{fish} based on immunological toxicity are lower than those based on reproductive toxicity, only RBC_{fish} for the immunological endpoint are presented.

(2) Value includes source fraction of 0.5. Central tendency and subsistence anglers are assumed to take all fish from the Kalamazoo River.

The RBC_{fish} protective of the central tendency sport angler consuming approximately 24 meals/year of fish, or an average daily ingestion rate of 0.015 kilograms/day (kg/day), is 0.109 mg/kg in fish fillet for the cancer endpoint and 0.187 for the noncancer endpoint (immunological). The RBC_{fish} protective of the high-end sport angler consuming up to 125 meals/year, or an average daily ingestion rate of

0.078 kg/day, is 0.042 mg/kg for the cancer endpoint and 0.072 for the noncancer endpoint. The RBC_{fish} protective of the subsistence angler consuming up to 179 meals/year, or an average daily ingestion rate of 0.11 kg/day, is 0.015 mg/kg protective for the cancer endpoint and 0.025 for the noncancer endpoint.

The MDCH has established criteria for placing fish on the Michigan Sport Fish Consumption Advisory. For the general population, when between 11 and 49 percent of samples exceed 2 mg/kg in fish, a one-meal/week advisory is issued; when greater than 50 percent of fish samples exceed 2 mg/kg, a no consumption advisory is issued. For women of childbearing age and children under 15 years of age, at concentrations greater than 0.05 mg/kg up to 0.2 mg/kg of PCBs in fish, a one-meal/week advisory is issued. At concentrations greater than 0.2 mg/kg, up to 1 mg/kg of PCBs in fish, a one-meal/month advisory is issued. At concentrations greater than 1.0 mg/kg up to 1.9 mg/kg of PCBs in fish, a six-meal/year advisory is issued. At concentrations above 1.9 mg/kg, a no consumption advisory is issued.

The MDCH considers their PCB fish advisory concentration of less than or equal to 0.05 mg/kg in fish to be protective at an ingestion rate of 225 meals/year (0.14 kg/day) for the general population for noncancer endpoints. The MDCH does not base its advisory on cancer risk, due to political and pragmatic considerations. For subsistence anglers, who have been reported to consume between three to four meals/week, the RBC_{fish} developed in this HHRA indicate that concentrations in the range of 0.015 mg/kg (cancer) and 0.025 mg/kg (noncancer) are needed to be protective of health. The differences between the derivations of the two noncancer values are listed in Table 6-2:

Table 6-2 Comparison of MDCH and HHRA Exposure Parameters

	MDCH	HHRA
Meals/year	225	179
Average daily fish consumption (kg)	0.14	0.11
Reduction by cleaning/cooking (%)	50	50
Weight of subject (kg)	70	70
Target dose, HPV or RfD (μg/kg/day)	0.05	0.02
PCB level in fish (mg/kg)	0.05	0.015

Most of the difference between the two results can be attributed to the difference between the health protection value (HPV) used by the MDCH (0.05 μg/kg/day) and the EPA RfD used in the HHRA (0.02 μg/kg/day). These values were derived from the same data by different methodologies. The Great Lakes Fish Advisory Task Force used a "weight of evidence" approach to derive the HPV used by the MDCH from data on a wide range of health effect endpoints. EPA derives RfDs from data on specific endpoints with uncertainty and modifying factors added.

The MDCH Division of Environmental Epidemiology has reviewed this document and considers it to be adequately consistent with the MDCH protocol for issuing fish consumption advisories. Although differences exist between RBC_{fish} and the MDCH first Level of Concern as cited above, MDCH considers that parameters and

assumptions used in the two derivations are reasonable, the resulting levels to be reasonably close, and the RBC_{fish} levels to be more protective than the MDCH Level of Concern. MDCH acknowledges EPA and MDEQ's authority to establish the cleanup levels to be used at any site.

6.2 Calculation of Risk-Based Sediment Concentrations

The RBC_{fish} were used to develop RBC_{sed}. RBC_{sed} represent sediment concentrations protective of fish that are consumed at the ingestion rates specified for sport and subsistence anglers. In 1994, EPA Region V completed a draft guidance document, which presented an overview of available methods for developing RBCs and recommended the biota-to-sediment accumulation factor (BSAF) method. Three methods, the bioconcentration factor (BCF) method, the bioaccumulation factor (BAF) method, and the BSAF were evaluated. The BCF and BSAF methods relate fish tissue concentrations to water column concentrations and prey consumption whereas the BSAF method relates fish concentrations to sediment (Pelka 1998). Methods were tested by comparing predicted fish concentrations with actual fish data for four locations: Saginaw, Michigan; Buffalo, New York; Ontario, Canada; and Manistique, Michigan. EPA Region V determined that the BSAF approach consistently gave the most reliable estimates of fish concentration relative to other methods.

Guidance provided by EPA Region V on the BSAF approach was used to develop the risk-based concentrations for sediment. This approach has been described in Bioaccumulation Models and Applications: Setting Sediment Cleanup Goals in the Great Lakes (*Proceedings of the National Sediment Bioaccumulation Conference*, September 11-13, 1996, presented by Amy Pelka, EPA, Region V. EPA 823-R-98-002) and in other technical memorandum.

BSAFs and RBC_{sed} were calculated for each of seven ABSAs and site wide. BSAFs were based on lipid normalized fish fillet PCB concentrations and organic carbon normalized sediment concentrations. RBC_{sed} were calculated based on a range of RBC_{fish} developed in the HHRA. To understand the uncertainty associated with the normalized data, and to estimate 95% confidence limits, a "bootstrapping" approach was used (Efron 1982). This approach involved random sampling with replacement from the underlying data on an ABSA-by-ABSA (or reach by reach) and species fillet basis and calculation of the BSAF and RBC_{sed} for each of these data subsets. This process was repeated 5,000 times to generate an estimate of the sampling distribution of BSAFs and RBC_{sed} by fish species, river reach, and site wide. This method used data only when PCB and TOC data were available for the same sediment sample, and PCB and % lipid from the same fish fillet. Tables 6-3 and 6-4 present the results of this analysis along with applicable summary statistics for smallmouth bass and carp.

The tables present the results on an ABSA-by-ABSA basis as well as a sitewide basis. No biological, physical, or chemical basis has been identified that would suggest that BSAFs would be greatly different among ABSAs for the BSAF to vary greatly among stream reaches. Differences in BSAF probably represent variability in measurements

and uncertainties in the BSAF model. Thus, for risk assessment purposes, pooled data from all areas was used for final calculations of RBC_{sed}. The full analysis and description of the bootstrapping algorithm are presented in Appendix A.

Table 6-3 Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Human Health Risk Assessment Biota/Sediment Accumulation Factors, Bootstrap Distributions of BSAF for Smallmouth Bass

ABSA	BSAF[1]	Bootstrap BSAF Distribution			
		Mean	Median	LCL95	UCL95
3	0.296	0.314	0.301	0.182	0.515
4	0.604	0.669	0.620	0.343	1.261
5	0.432	0.638	0.443	0.194	1.916
6	0.092	0.208	0.099	0.028	0.891
7	0.371	0.470	0.393	0.183	1.161
8	2.296	2.590	2.373	1.303	5.148
9	0.708	0.755	0.723	0.438	1.249
Sitewide Average of ABSAs	0.686	0.806	0.707	0.382	1.735
Sitewide Average all fish and sediment pooled	0.444	0.456	0.449	0.307	0.643

[1] BSAF calculated as $(PCB_{fish\ fillet}/ \%\ lipid)/ (PCB_{sed}/ \%\ TOC)$

Table 6-4 Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Human Health Risk Assessment Biota/Sediment Accumulation Factors, Bootstrap Distributions of BSAF for Common Carp

ABSA	BSAF[1]	Bootstrap BSAF Distribution			
		Mean	Median	LCL95	UCL95
3	0.523	0.557	0.536	0.302	0.939
4	1.113	1.235	1.155	0.636	2.298
5	0.313	0.466	0.332	0.143	1.455
6	0.202	0.463	0.219	0.068	1.954
7	0.275	0.341	0.288	0.124	0.861
8	3.437	3.854	3.506	1.807	7.990
9	0.935	0.991	0.950	0.554	1.677
Sitewide Average of ABSAs	0.971	1.130	0.998	0.519	2.453
Sitewide Average all fish and sediment pooled	0.641	0.661	0.651	0.439	0.949

[1] BSAF calculated as $(PCB_{fish\ fillet}/ \%\ lipid)/ (PCB_{sed}/ \%\ TOC)$

Sitewide BSAFs for carp and smallmouth bass were calculated for the API/PC/KR site. Using synoptic data for fish and sediment, BSAFs of 0.456 and 0.661 were derived for smallmouth bass and carp, respectively (Spectrum Consulting Services 2001). BSAFs were calculated as

$$\mathbf{BSAF = (PCB_{fish\ fillet} / \%\ lipid) / (PCB_{sed} / \%\ TOC)}$$

Using site-specific BSAFs, the following equation can be used to derive RBC_{sed}:

$$\mathbf{Concentration_{sediment} = (toc * RBC_{fish}) / (BSAF * \% lipid)}$$

Where: Sitewide TOC (total organic carbon) = 0.0279%
Sitewide BSAF 0.444 (bass); 0.641 (carp)
Sitewide lipid 0.013 (bass); 0.0358 (carp)
Risk-based fish concentrations =
0.109 (mg/kg) central tendency sport
0.042 (mg/kg) high end sport anglers
0.015 (mg/kg) subsistence anglers
Hazard-based fish concentrations, based on immunological endpoint =
0.187 (mg/kg) central tendency sport anglers
0.072 (mg/kg) high end sport anglers
0.025 (mg/kg) subsistence

RBC_{sed} are presented in Table 6-5. RBCs are different depending on the species consumed. For the central tendency sport angler, if ingestion of only smallmouth bass is assumed, the RBC_{sed} is 0.51 mg/kg for the cancer endpoint and 0.88 mg/kg for the noncancer endpoint (immunological). If ingestion of a combination of smallmouth bass and carp is assumed, the RBCsed is 0.30 mg/kg for the cancer endpoint and 0.52 mg/kg for the noncancer endpoint.

For the high end sport angler, if ingestion of smallmouth bass is assumed, the RBC_{sed} is 0.20 mg/kg for the cancer endpoint, 0.34 mg/kg for the noncancer endpoint. If ingestion of a combination of smallmouth bass and carp is assumed, the RBCsed is 0.12 mg/kg for cancer endpoints and 0.20 for the noncancer endpoint.

Table 6-5 Risk-Based Sediment Concentration (RBC_{sed}) API/PC/KR SITE

Scenario	RBC_{sed} Protective of Fish Ingestion at 1E-05 Cancer Risk for PCBs (mg/kg)		RBC_{sed} Protective of Fish Ingestion at 1.0 Hazard Quotient for PCBs (mg/kg)	
	Bass	Bass/Carp	Bass	Bass/Carp
Sport Angler - Central Tendency	0.51	0.30	0.88	0.52
Sport Angler - High End	0.20	0.12	0.34	0.20
Subsistence Angler	0.07	0.04	0.12	0.07

For the subsistence angler, if ingestion of smallmouth bass is assumed, the RBC_{sed} is 0.07 mg/kg for the cancer endpoint and 0.12 mg/kg for the noncancer endpoint. If ingestion of a combination of smallmouth bass and carp is being protected, the RBC_{sed} is 0.04 for the cancer endpoint and 0.07 mg/kg for the noncancer endpoint.

6.3 Calculation of Risk-Based Soil Concentrations

The risk-based floodplain soil concentration (RBC_{soil}) were derived in the same manner as the RBC_{fish}, i.e., the risk and hazard algorithms were reversed and were

solved using a cancer risk of 1 in 100,000 and a hazard index of 1.0. The same exposure assumptions used to estimate risk and hazard were used to derive RBC_{soil}.

Table 6-6 presents RBC_{soil} protective of residents. RBC_{soil} protective of residents for the cancer endpoint is 2.5 mg/kg. For noncancer endpoints, RBC_{soil} is 15 mg/kg for the reproductive endpoint and 4 mg/kg for the immunological endpoint.

Table 6-6 Risk-Based Floodplain Soil Concentrations (RBC_{soil}) Protective of Residents API/PC/KR Site

Receptor	RBC_{soil} Protective of 1E-05 Cancer Risk (mg/kg)	RBC_{soil} Protective of 1.0 Hazard Index (mg/kg)
Resident	2.5	15 (R) 4.0 (I)

Notes (R) = Reproductive endpoint
(I) = Immunological endpoint

Table 6-7 presents the RBC_{soil} protective of recreationalists. For the cancer endpoint the RBC_{soil} is 23 mg/kg. For noncancer endpoints, the RBC_{soil} is 139 mg/kg for the reproductive endpoint and 32 mg/kg for the immunological endpoint.

Table 6-7 Risk-Based Floodplain Soil Concentrations (RBC_{soil}) Protective of Recreational Visitors API/PC/KR Site

Receptor	RBC_{soil} Protective of 1E-05 Cancer Risk (mg/kg)	RBC_{soil} Protective of 1.0 Hazard Index (mg/kg)
Resident	23	139 (R) 32 (I)

Notes: (R) = Reproductive endpoint
(I) = Immunological endpoint

Appendix A presents the spreadsheets used to derive RBCs.

6.4 Applicability of RBC_{sed}

RBC_{sed} calculated for protection of angler assume that sediments are in-stream, or could reasonably become in-stream due to erosion or flooding. RBC_{sed} also assume a wide range of fish consumption for the three angle scenarios. Different angler scenarios could conceivably apply to different stream reaches, since angling success may vary significantly among ABSAs. For example, ABSA 9, Lake Allegan, appears to be a poorer fishery than other reaches of the river system. Data do not appear to be available, however, to allow a quantitative approach to different fishing behavior in different stream reaches.

RBC_{sed} calculated to protect residents might apply most directly to those areas immediately adjacent to former impoundment areas that could be visited on an almost daily basis by people living on the edge of the floodplain. Observations for

some homes and yards that are located on adjacent to floodplain soils indicate the potential for ongoing exposure.

RBC_{sed} may be applicable anywhere in the floodplain where exposed soils/sediments contaminated with paper waste exist. The focus of the risk assessment for recreational exposures was on the former impoundment areas, and these areas may well represent most of the more attractive recreational areas with exposed contaminated soils/sediments within the site. However, RBC_{sed} for recreational exposures would be equally applicable to accessible sites where contaminated exposed soils/sediments exist anywhere along the river.

6.5 Comparison of RBC Based on Human Health and Ecological Risk

CDM (2001) prepared a comprehensive ecological risk assessment (ERA), based on many of the same site data, as a companion to this HHRA. This ERA also develop a range of RBC for several important receptors. The range of RBC based on protection of riverine and upland species, is not greatly different than the range of RBC developed based on risks and hazards to human health. For all sediments that can be assumed to be part of the aquatic environment, RBCs based on protection of mink range from 0.5 to 0.6 mg/kg (Figure 6-1). The range in Table 6-4, from 0.04 mg/kg (subsistence angler, cancer endpoint, bass/carp diet) to 0.88 mg/kg (sport angler CTE, immunological endpoint, bass only diet), overlaps substantially with this range. Protection of both human and ecological receptors can apparently be achieved for pathways associated with contamination of aquatic habitats using much the same target sediment values.

Similarly, the range of RBC for protection of upland species (great horned owl, robin, mouse, and fox) range from 2.9 to 63 mg/kg (Figure 6-2). Again this range overlaps to a great extent with the range of values in Tables 6-5 and 6-6 (2.5 to 139 depending on receptor and toxicological endpoint). If a decision is made to manage risk for exposed floodplain soil on some basis other than as a source to river sediment, again, protection of human and ecological receptors might be achieved with similar target soil/sediment concentrations.

Figure 6-1

Figure 6-2

Protective Threshold Sediments/Surface Water PCB Concentrations for Mink

Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site

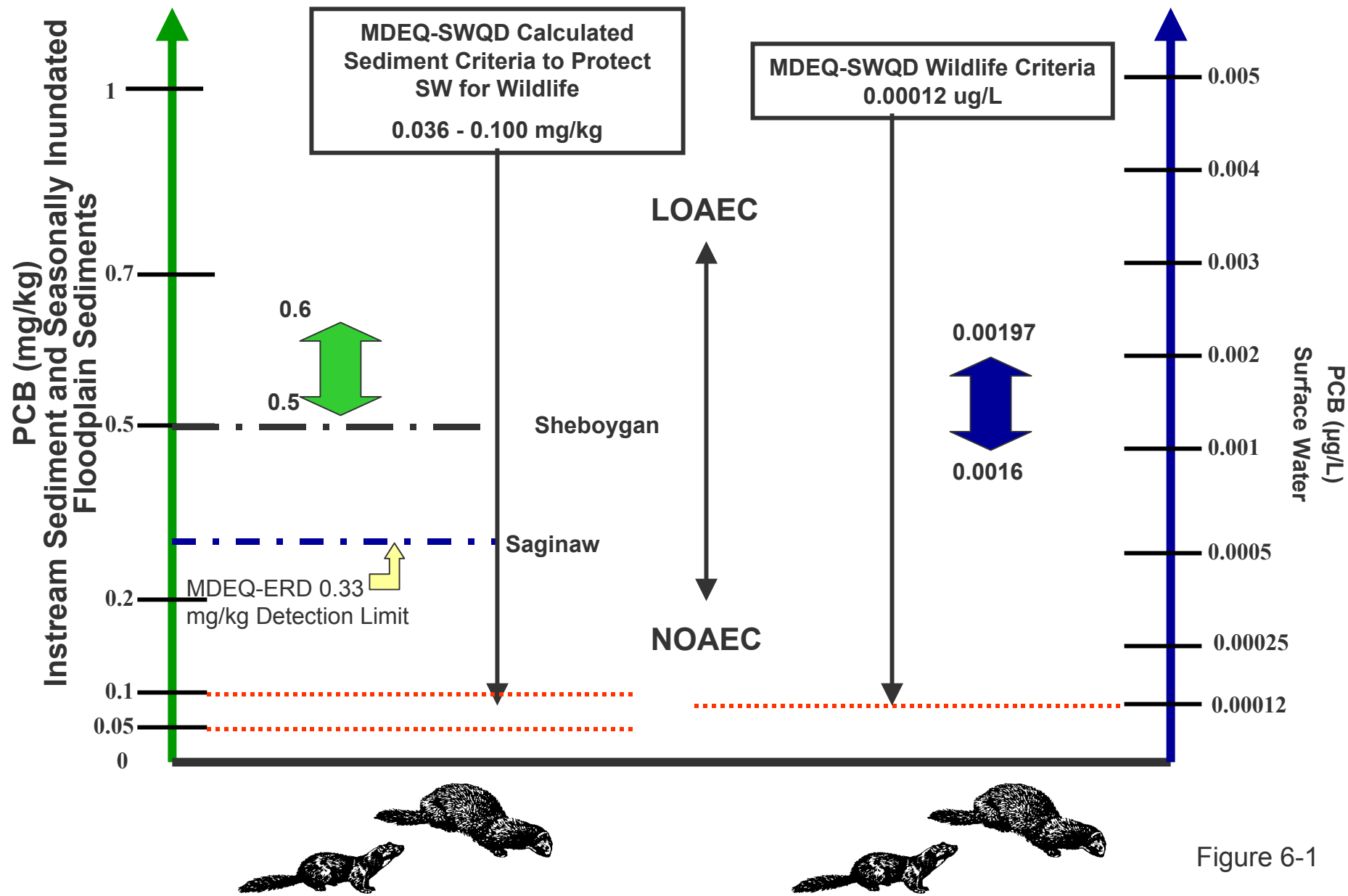

Figure 6-1

Protective Threshold PCB Surface Soil Concentrations (Range for NOAEC – LOAEC) for Ecological Receptors

Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site

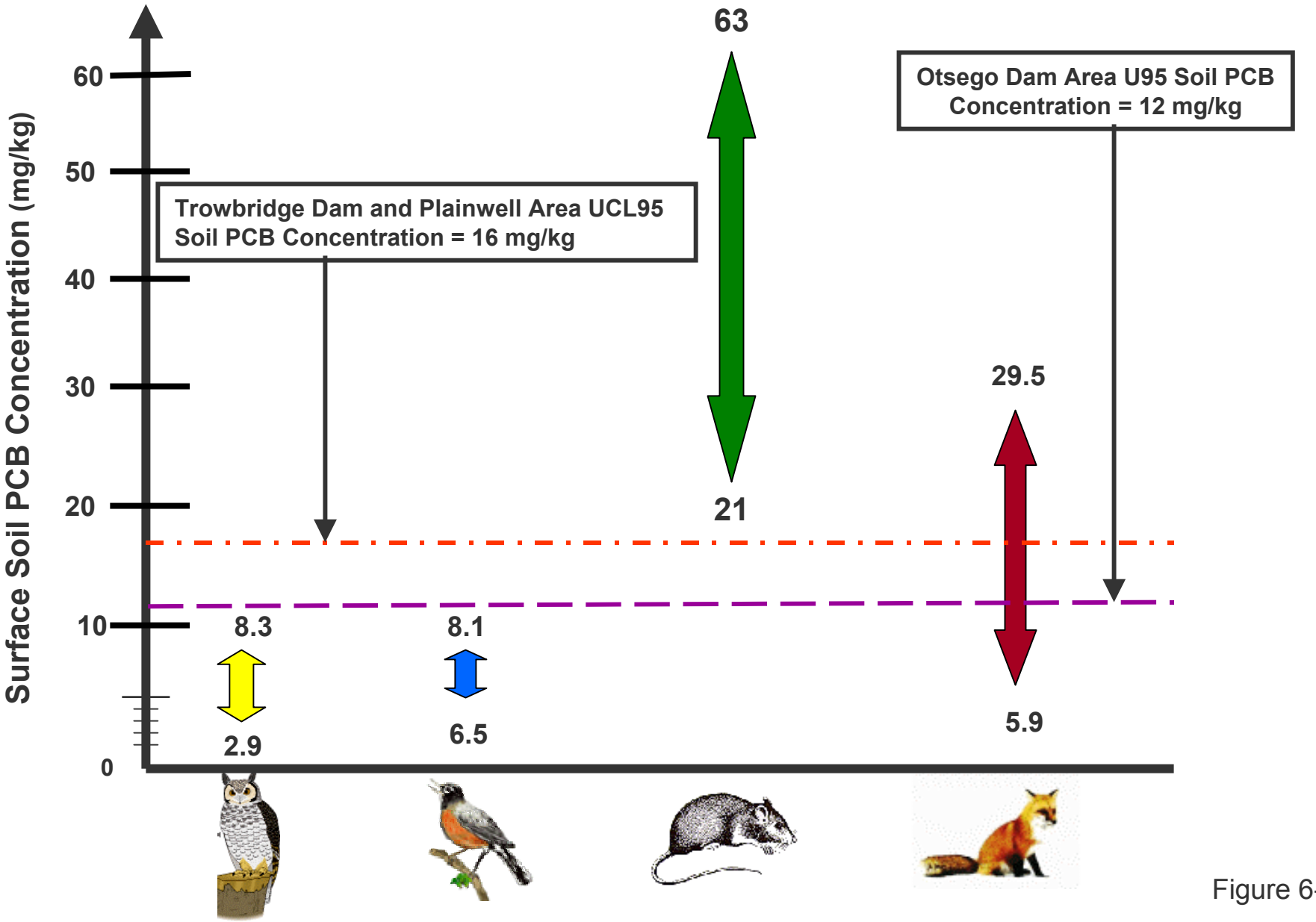

Figure 6-2